MINISTRY OF HOUSING AND
LOCAL GOVERNMENT

ACCIDENTS IN SEWERS

REPORT ON THE PRECAUTIONS NECESSARY FOR THE SAFETY OF PERSONS ENTERING SEWERS AND SEWAGE TANKS

(Being a reprint, without substantial alteration, of the Report submitted to the Minister of Health, and first published by H.M. Stationery Office in 1934)

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The Rt. Hon. Sir John Gilmour, Bt., D.S.O., M.P.

The Rt. Hon. Sir E. Hilton Young, G.B.E., D.S.O., D.S.C., M.P.

Gentlemen,

1. We have the honour to report that in July, 1933, we were appointed as representatives of the Home Office and the Ministry of Health to investigate and advise on the precautions necessary for the safety of persons entering sewers and sewage tanks, and the desirability of issuing a pamphlet on the subject or taking other steps towards securing that the necessary precautions are observed. The decision to investigate these matters was reached because of fatal accidents which had recently occurred at Upminster and Southend, and because of the absence of any record of an investigation having been made or advice given previously by any Government Department. Since our appointment further fatal accidents have occurred at Northallerton and Coventry.

2. In our inquiry into the causes of accidents in sewers and sewage tanks, we have not considered questions pertaining to accidents which might occur during the execution of constructional or engineering work or questions affecting sewers and sewage tanks into which no sewage has yet passed. Further, as tanks in use at sewage works serve varying purposes, the expression is here used to include pump-wells, storage, sedimentation and septic tanks as well as tanks in which sewage sludge is stored pending disposal, or in which it is allowed to undergo digestion with a view to collecting the fermentation gases or otherwise facilitating further treatment.

3. We have been greatly assisted by the following persons who have been good enough to give evidence before us :—

Mr. T. P. Frank, Chief Engineer, London County Council.

Mr. A. T. Gooseman, Institution of Municipal and County Engineers.

Mr. D. C. Graham, Divisional Engineer, London County Council.

Sir George Humphreys, K.B.E., Past President, Institution of Civil Engineers.

Major L. Roseveare, President, Institution of Municipal and County Engineers.

Mr. J. D. Watson, Vice President, Institution of Civil Engineers.

Mr. H. C. Whitehead, Engineer to the Birmingham, Tame and Rea District Drainage Board.

Colonel Thomas, C.B.E., Chief Inspector of Explosives, Home Office, also attended one of our meetings and gave us the benefit of his wide experience of explosive materials.

4. One of our first steps was to circularise the Metropolitan Borough Councils and a number of other Local Authorities to ascertain whether any and if so what regulations were made by them in regard to precautions to be taken by men working in sewers or sewage tanks. The replies confirmed our impression that while certain of the larger authorities had issued fairly comprehensive instructions to their employees, there was a lack of uniformity in the instructions issued and many Local Authorities had either issued no instructions at all or done so perfunctorily.

5. We also communicated with the responsible officials in a number of large towns in Germany and U.S.A. and obtained from them comprehensive and valuable information as to the extent of the problem and the practice as to the precautions in those towns.

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Classes of Danger

6. Dangers which may be anticipated in sewers and sewage tanks fall naturally under two heads:—

(1) Flooding.

(2) Gases.

- (*a*) asphyxiating gases.
- (*b*) poisonous gases.
- (*c*) inflammable gases.

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Flooding

7. The danger of injury to men working in a sewer through the sudden rush of sewage or water is likely to arise from (*a*) storms ; (*b*) abnormal tide action in sewers under tidal influence or (*c*) the sudden releasing of large volumes of sewage. The occurrence of (*a*) and (*b*) cannot generally be anticipated and reliance must be placed on the alertness of the staff. As regards (*c*) such an occurrence could arise only from lack of co-ordination between the persons responsible for the discharge of sewage and the persons in charge of men working in the sewers.

It is our view, and this has been agreed generally by our witnesses, that it is highly desirable that bars or chains should be provided at all man-holes in sewers in which men can work so that they can be fixed across the sewer at the manhole below the point at which any man is working.

Gases in Sewers and Sewage Tanks

Gases in Sewers

8. The composition of the atmosphere in sewers normally varies very little from that of the outside atmosphere. In certain circumstances, however, it is possible for the atmosphere in sewers to be considerably modified in composition either as a result of relative stagnation of the sewage due to structural defects in the sewers or by the wilful or accidental admission into the sewers of gases such as coal gas or of liquids which readily vaporise.

9. In sewers which are laid at a very flat gradient or which have been subject to subsidence it often happens that the sewage is comparatively stagnant and that the solid matters in the sewage settle out and remain lodged in one position. These solids, if they remain long enough, undergo fermentation and absorb oxygen from the air in the sewer. If the air is comparatively stagnant its composition is quickly altered both by the emission of fermentation gases and by the absorption of the oxygen.

The fermentation or digestion of sewage solids gives rise in the early stages to very objectionable odours and an acid condition of the solids. The gases evolved at this stage are mainly carbon-dioxide, hydrogen, sulphuretted hydrogen and some methane. As the fermentation proceeds the solids become alkaline in character due to the predominance of other organisms and the gases evolved consist very largely of a mixture of methane (60 per cent. to 80 per cent.) and carbon-dioxide (15 per cent. to 20 per cent.).

10. It will be obvious that if the air in the sewer is comparatively stagnant these evolved gases will collect and gradually displace the air with the result that the sewer atmosphere will become irrespirable owing to the reduction of its oxygen content, and even explosive owing to the presence of the inflammable gas methane. Sulphuretted hydrogen is also inflammable but is hardly likely to occur in sufficient quantities to give an explosive

mixture. This gas is, however, very poisonous; when present to the extent of 1 volume in 10,000 volumes of air it is dangerous to health and in a concentration of 1 volume in 1,000 it is rapidly fatal.

11. When the oxygen of the inspired air is diminished from the normal 21 per cent. to values between 16 per cent. and 12 per cent., that is, somewhat beyond the point at which the flame of a safety lamp is extinguished, the first perceptible sign of anoxaemia develop. When it is diminished to values between 14 per cent. and 9 per cent. serious interference with the nervous and muscular functions ensues. When the oxygen is diminished to values between 10 per cent. and 6 per cent. loss of consciousness occurs and below this point respiration is quickly arrested and death supervenes. (See Noxious Gases. Henderson and Haggard, 1927, p. 98.)

This reduction of the proportion of oxygen in the atmosphere may be effected either by absorption of the oxygen by sewage or sewage solids or by admixture of the air with the gases evolved during the fermentation of the sewage solids.

12. Of the gases found at times in sewer air due to direct admission, coal gas is perhaps the most common. Acetylene resulting from the decomposition of unspent calcium carbide is occasionally found. Both coal gas and acetylene may give rise to explosive mixtures in the sewers, the lower and upper explosive limits of coal gas being 7.5 per cent. and 24 per cent. by volume and of acetylene 3 per cent. and 80 per cent. respectively. Owing to its content of carbon-monoxide coal gas is a dangerous poison in a concentration much below that which produces an explosive mixture. The possibility of other gases gaining admission to the sewers should not be overlooked, especially where industrial premises are concerned, and cases have been known where nitrous gases resulting from acid discharges have been found in the sewers. Such acid discharges are also liable to cause the evolution of carbon-dioxide or sulphuretted hydrogen when mixed with other discharges containing carbonates or sulphides.

13. Of the liquids which readily vaporise and are sometimes found in sewers inflammable liquids, e.g. from dry cleaning establishments and chemical works, are occasionally met with, but petrol is by far the most common. The chief danger from these liquids is that their vapours will form inflammable mixtures with the air in the sewers and an air petrol mixture containing 2 per cent. or 3 per cent. of petrol vapour by volume is very explosive. The ease with which such an explosive mixture can be formed may be gauged from the fact that 1 volume of liquid petrol will give rise to about 160 volumes of petrol vapour. Apart from the danger by explosion, petrol vapour is a dangerous poison when present in the air in a concentration of between 1 per cent. and 2 per cent.

Gases in Sewage tanks

14. In general, what has been said above regarding gases in sewers applies to gases in sewage tanks, but it must be borne in mind that the form of construction of the tanks and the purposes which they have to serve may increase the danger of the presence of gases. The sewage flowing in a system of sewers tends to carry along with it the gases present in the sewers and where the system ends in a covered-in storage tank or pump-well these gases, in so far as they are heavier than air, collect on the surface of the sewage there and gradually displace the air. The gases may give rise to asphyxiation, poisoning or explosion according to their composition. If the system ends in a storage tank or pump-well open to the atmosphere and not so deep as to prevent the sewer gases from diffusing into the atmosphere, little danger is to be anticipated.

15. In sedimentation and septic tanks the gases which are evolved are the same as those to which reference has been made when dealing with the fermentation of sewage solids in the sewers. The difference between a sedimentation tank and septic tank is mainly a difference of size in relation to the daily volume of sewage treated and a difference in the method of allowing the sewage to enter and leave the tank. In sedimentation tanks the size is small in relation to the flow ; the tank is usually open to the air ; the sewage is allowed to enter and leave the tank near the surface so that the formation of a scum is avoided, and sludge is removed more frequently than from a septic tank. In septic tanks the size is large in proportion to the flow ; the sewage is allowed to enter and leave the tank below the surface of the liquid so that the formation of a scum is encouraged ; sludge is removed at very infrequent intervals, and the tank is often covered. The solids which collect in sedimentation and septic tanks undergo the type of fermentation which has been described in connection with sewage solids which collect in sewers and it will be evident from the descriptions of these types of tanks that fermentation is much more vigorous and prolonged in septic tanks than in sedimentation tanks. It will also be evident that if sedimentation tanks are not frequently cleansed of sewage solids they are liable to function as septic tanks.

Speaking generally, the gases which are to be feared in sedimentation tanks are those which are produced in the early stages of the fermentation of sewage solids, namely, carbon-dioxide and sulphuretted hydrogen, whereas the gases which are to be feared in septic tanks are those which are evolved in the later stages of the fermentation of sewage solids, namely, methane and carbon-dioxide. There is, of course, less danger to be feared from tanks which are open and well ventilated than from those which are covered in.

16. Of recent years there has been a tendency to adopt a form of construction of sedimentation tank from which the sludge can be removed without men having to enter the tank. At first this object was attained by constructing deep tanks with steep sides so that the sludge fell to a pointed bottom and could be removed by opening a valve, but latterly the tendency has been to construct flat-bottomed tanks with mechanical scrapers.

17. In sewage tanks which are used for the storage and fermentation or digestion of sewage solids the dangers which, as mentioned above, arise in septic tanks may be accentuated. The tanks contain the solids separated from the sewage and these undergo the fermentation which has been described above. Storage tanks, unless they are below ground, are usually open to the air and well ventilated ; they may take the form of :—

(*a*) pump-wells to receive sludge (from sedimentation and septic tanks) which has to be pumped for further disposal ;

(*b*) tanks in which a certain amount of water separates so that the sludge is concentrated and the volume of sludge which has to be otherwise dealt with is reduced ;

(*c*) tanks in which the sludge is merely stored before it is discharged into barges for disposal at sea, and

(*d*) tanks in which the sewage is designedly allowed to undergo digestion for the purpose of obtaining gas and facilitating the ultimate disposal of the sludge.

From the purposes which these tanks have to serve it will be evident that the greatest danger may be looked for in sludge digestion tanks and the least in open storage tanks. The gases evolved are the same as those which, as mentioned above, arise from the decomposition of sewage solids in sewers, and in the absence of precautions there is grave risk of asphyxiation, explosion, or poisoning wherever these gases collect.

Asphyxiation

18. Only by adequate ventilation can irrespirable gases be removed from the sewer or sewage tank and the danger of asphyxiation obviated. To this end sewers should be laid with a self-cleansing gradient and with a sufficient number of manholes to ensure adequate ventilation. Tanks should where possible be open to the air, an arrangement which will not only assist ventilation but also facilitate access and egress.

Explosion

19. It has been impressed upon us that the admission of petrol into the sewers is highly dangerous, and that there should be the greatest strictness in guarding against its admission. We have been fortunate in this country in that there has been no very serious accident due to petrol in sewers, but the experience abroad, particularly in Canada and the United States, shows that most devastating accidents may occur through petrol.

Petrol is transported by road in bulk, and in the event of the tank wagon springing a leak through collision or other cause, the overflowing petrol will generally find its way along the gutters of the roadway into the sewers. It is, of course, impossible to provide against pure accidents, and the existing regulations concerning the construction of tank wagons are considered by the Home Office to be satisfactory. All that can be done is to suggest that whenever possible (though we fear this would be rare), the petrol should be emptied from the damaged tank on to waste ground, if an accident should occur. In the event of a large quantity of petrol being thrown into the roadway, either the police or the fire brigade should be in a position to inform the sewer authority in order that any men working in sewers likely to be affected by the intake of petrol may be withdrawn. No men, of course, should be allowed to enter any affected sewer until it had been determined that the petrol vapour had been finally dispersed.

Petrol might enter sewers from garages. So far as the private garage is concerned, there is general agreement that little or no danger of petrol entering sewers arises. Any small quantities of petrol spilt in a small garage would be likely to evaporate before it reached a drain.

Larger garages, for example repair garages having workshops attached, fall within a different category. There, larger quantities of petrol are handled, and the risk of material quantities of petrol reaching the sewers is increased, but under the general law special precautions have been taken to prevent it.

The use of petrol or similar liquids for cleaning purposes in private houses is growing and the practice which no doubt prevails of disposing of the petrol into drains cannot be too strongly deprecated. In this connection we think it may be useful to quote the following remarks in the Report of H.M. Inspector of Explosives for 1932:—

> "Petrol should never be exposed except to the minutest extent in the house, and it must never be thrown down a drain or sink . . . by so doing a fatal explosion may result in a drain or sewer. Waste petrol should be disposed of on open ground which for a time must be regarded as a danger zone".

Poisoning

20. Our evidence clearly points to this danger, particularly from sulphuretted hydrogen, being the gravest encountered in sewers and sewage tanks. The danger of the accumulation of the gases will correspond with

the extent to which solids are allowed to collect in obstructed sewers or in sewage tanks. Further, where sewage solids collect and decompose a crust tends to form on the surface of the sludge under which the gases are generated and retained. Disturbance of the sludge releases the gases and might lead to dangerous conditions. Thus, a sewer or sewage tank found to be safe before being entered would, under such circumstances, be liable to become dangerous after the men are at work. One of the first essentials, therefore, and this in our view cannot be stressed too strongly, is to prevent the accumulation of sewage or sludge by cleaning out tanks and where necessary, sewers at frequent intervals. This need, we fear, has been overlooked in many places in the past.

Precautions and Tests

21. In referring above to the various classes of danger we have indicated various preventive measures which ought in our view to be taken in the construction and general management of works of sewerage and sewage disposal to minimise the risk of dangerous conditions in sewers and tanks. Danger is most likely to arise in old, ill-designed sewers and tanks, but we would emphasise that in all cases where men are entering sewers or tanks, tests should be made of the conditions and precautions taken for safety. The necessary tests and precautions are relatively simple and if carefully attended to should ensure safety.

22. Before a man enters a sewer or tank, it should be ventilated ; in the case of a sewer by the removal for a period of at least half an hour of the covers of the manhole by which the man is to enter and the manhole next on either side. Then the following tests should always be made :—

(i) For sulphuretted hydrogen by exposing moistened lead acetate paper for 5 minutes. So long as this gas is present the sewer or tank should on no account be entered without special breathing apparatus.

(ii) For asphyxiating conditions by a safety lamp. The lamp should burn continuously for at least 5 minutes before the sewer or tank is entered.

(iii) For inflammable gases by a suitable detector lamp.

It need hardly be stressed that some competent person should be charged with the duty of seeing that the lamps are undamaged before they are allowed to be used.

23. A lifeline should always be worn by the first man entering a sewer or tank until the safety of the sewer or tank has been established. So long as a man is in the sewer, the three manholes (the one entered and that on either side) should be kept open and two men should be posted at the entry manhole. In the case of extensive inspection of sewers, sufficient manholes should be opened to secure through ventilation.

On no account should smoking in sewers or tanks be permitted, or naked lights used, or matches struck. Only safety lamps should be used.

24. It is of course imperative that the men should be well versed in the tests to be made and should have impressed upon them the need for carefully carrying them out. Full instructions should be prepared by the Local Authority for the guidance of the men, but we are not impressed with the efficacy merely of printed instructions posted up at the works or handed to the men. We consider it highly desirable that before a man is employed on this class of work he should receive instruction from a responsible official of the Local Authority, who should certify that the man has full knowledge

of the instructions; and also that arrangements should be made whereby the men should, at intervals, demonstrate before a responsible official their practical knowledge of the tests and precautions to be taken.

25. If the tests and precautions referred to above are properly observed, the risk of accidents should be reduced to a negligible quantity. Local arrangements, however, should be made for the police and fire brigade (where one is maintained) to be notified if an accident should occur. To facilitate such notification in the event of accidents occurring at or near a sewage works, a telephone should wherever practicable be installed at the works. Sewage disposal works where covered tanks or sludge digestion tanks are installed should also be equipped with a properly maintained rescue kit and resuscitation apparatus.

26. We consider that rescue kit should always be carried by each travelling sewer gang. It must be borne in mind, however, that the workmen in the normal course of their duties will carry much in the way of tools and tackle and in order that confusion in the event of emergency may be avoided, it should be a strict rule that the rescue kit should be kept in a box or chest separate from the tools and tackle. The foreman in charge of the gang, or senior man, if the foreman is not present, should be held responsible for the rescue kit being available.

27. The rescue kit referred to in paragraphs 25 and 26 should include:—

(*a*) at least two lifelines of suitable length.

(*b*) one breathing apparatus, either of the air-hose or self-contained oxygen type.

This kit should be regularly examined and maintained in an efficient condition.

28. We do not consider that any legislation is warranted at the present time but we recommend that a summary of our conclusions should be issued as a pamphlet to all sewerage and sewage disposal authorities. Copies also might be supplied to appropriate journals. A suggestion for the form which such a pamphlet might take is appended.

29. The Committee desire to place on record their appreciation of the great assistance they have received from their Secretary, Mr. S. F. Dellow. He has done a great deal of work in collecting and preparing for the Committee, records of cases of accidents and, also, in preparing drafts for the report.

We have the honour to be, Gentlemen,

Your obedient Servants,

R. G. HETHERINGTON,
Chairman.

I. F. ARMER.
J. H. BURRELL.
H. T. CALVERT.
THOS. CARNWATH.
L. C. McNAIR.
E. L. MIDDLETON.

S. F. DELLOW,
Secretary.
Ministry of Health,
*Whitehall, S.W.*1.

30th April, 1934.

APPENDIX

MEASURES FOR PREVENTING ACCIDENTS IN SEWERS AND SEWAGE TANKS

1. With reasonable care, accidents in sewers and sewage tanks should not occur, The tests and precautions to be taken to ensure safety are relatively simple but they must be strictly observed.

2. The atmosphere in a sewer or sewage tank, which normally varies very little indeed from that of the open air, may occasionally become irrespirable, poisonous or explosive, owing to the evolution of gases (carbon-dioxide, sulphuretted hydrogen and methane) and the absorption of oxygen in the fermentation of sewage solids and the admission, accidentally or wilfully, of gases such as coal gas or liquids which readily vaporize, such as petrol.

The atmosphere in a sewer or sewage tank is most likely to undergo a change in composition and become dangerous where the sewage is stagnant and ventilation inadequate. Sewers should therefore be laid with a self-cleansing gradient, and with a sufficient number of manholes to provide adequate ventilation, and tanks should, wherever possible, be open to the air, an arrangement which would not only secure ventilation but also facilitate access and egress.

Where sewage solids are stored for a long time, a crust tends to form on the surface, and when the crust is disturbed the gases which have been formed and retained by the crust are given off. It is essential, therefore, that tanks which are not open to the air should be cleaned out at intervals frequent enough to avoid such conditions.

3. To prevent accidents from flooding in a sewer, bars or chains should be provided at all manholes in large sewers so that they can be fixed across the sewer at the manhole below the point at which men are working.

4. Before a man enters a sewer or tank, it should be ventilated, in the case of a sewer by the removal for a period of at least half-an-hour of the covers of the manhole by which the man is to enter and of the manhole next on either side. Then tests should always be made in the following order:—

(1) For sulphuretted hydrogen, as described in "Methods for the Detection of Toxic Gases in Industry—Leaflet No. 1.—Hydrogen Sulphide" issued by the Department of Scientific and Industrial Research and published by H.M.S.O. Where, and so long as, an injurious concentration of this gas is thus detected, the sewer or tank should on no account be entered without special breathing apparatus ;

(2) For asphyxiating conditions by a safety lamp. The lamp should burn continuously for at least five minutes before the sewer is entered ;

(3) For inflammable gases, by a suitable detector lamp.

A competent person should be charged with the duty of seeing that the lamps are undamaged before they are allowed to be used, and of testing lamps at regular and frequent intervals.

5. The first man entering a sewer or tank should be secured by a lifeline until its safety has been established. So long as any man is in the sewer the three manholes (the one entered and that on either side) should be kept open, and two men posted at the entry manhole. In the case of extensive inspection of sewers, sufficient manholes should be opened to secure through ventilation.

6. On no account should smoking in a sewer or tank be permitted or naked lights used, or matches struck. Only safety lamps or preferably safety electric hand lamps which have greater illumination should be used.

7. It is imperative that the men should be well versed in the tests to be made and should have impressed upon them the need for carefully carrying them out. Full instructions should be prepared by the Local Authority for the guidance of the men. It will not be sufficient merely to arrange for printed instructions to be posted up at the works or handed to the men. Before a man is employed on this class of work he should receive instruction from a responsible official of the Local Authority and be certified to have full knowledge of the instructions. Arrangements should also be made for the men at intervals to demonstrate before a responsible official their practical knowledge of the tests and precautions to be taken.

8. Local arrangements should be made for the police and (where one is maintained) the fire brigade to be notified if an accident should occur. To facilitate this a telephone should, wherever practicable be installed at sewage disposal works. Sewage disposal works where covered tanks or sludge digestion tanks are installed should be equipped with a rescue kit and resuscitation apparatus.

9. Rescue kit should always be carried by each travelling sewer gang. This kit should be kept in a box or chest separate from the tools and tackle and the man in charge of a gang should be held responsible for the kit being available.

10. The rescue kit should include:—

(*a*) at least two lifelines of suitable length.

(*b*) one breathing apparatus, either of the air-hose or self-contained oxygen type.

This kit should be regularly examined and maintained in an efficient condition.

11. It is important, particularly where the larger drainage systems are involved, that the men should be fully familiar with the features of the works to be entered, and also with any possible hazards (such as the sudden discharge of storm-water) and the precautions necessary to meet them. Steps should invariably be taken to ensure this before entry is permitted.

NOTE.

Attention is also invited to the publication "Safety Measures in Sewers" published by the Institution of Civil Engineers, 1952.

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